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Control of Cherry Yellow-Leaf on Nursery Stock

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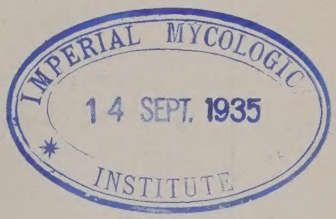

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George L. McNew and Donald E. Bliss[1]

YELLOW-LEAF, caused by the fungus *Coccomyces hiemalis* Higgins, is the most prevalent and destructive cherry disease in Iowa, since it often causes premature defoliation of both nursery and orchard trees. Early defoliation in nursery stock results in decreased growth during the current and subsequent years, and precludes all possibility of forcing the trees into marketable size in one growing season. In the orchard, defoliation may decrease fruit bud formation and vegetative growth and increase the amount of winterkilling.

All defoliated nursery stock must be held in the nursery row a second season, and even then many of the trees must be marketed at lower grades because of inferior size. Winterkilling in severely defoliated blocks is so common that yellow-leaf becomes the limiting factor in cherry culture.

Most studies on yellow-leaf of cherries have been made in orchards rather than in nursery plantings. In general, lime-sulphur and bordeaux mixture have been found most satisfactory, the former being generally preferred because it is less injurious to foliage and fruit. Bordeaux mixture has been credited with reducing the size of the fruit and injuring the foliage by Elmer (5) in Kansas, Talbert and Swartout (12) in Missouri, Dutton and Wells (4) in Michigan and Young (13) in Ohio, and by others. Consequently these men favored the use of lime-sulphur, but Keitt (8) and Keitt and Jones (1) in Wisconsin, Howitt (7) in Canada, and Bliss and McNew (3) in Iowa, recommended the use of bordeaux mixture.

Soon after introduction of spraying, nurserymen in the Missouri Valley resorted to bordeaux mixture in preference to the

[1] The investigations reported in this bulletin were conducted by the Botany and Plant Pathology Section under State project No. 83 of the Iowa Agricultural Experiment Station. The authors are deeply indebted to Dr. I. E. Melhus for directing the work and for valuable assistance in preparation of the manuscript. They also wish to thank the Mount Arbor and Shenandoah Nurseries of Shenandoah, Iowa, for supplying all the plant materials and rendering financial assistance until the work was organized as a state project.

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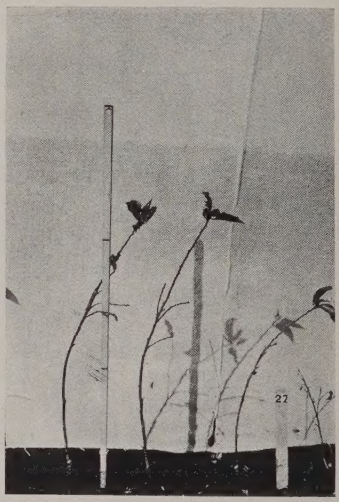

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Fig. 1. The amount of growth of cherries by the end of the second season is largely determined by the amount of yellow-leaf during the first season. The 2-year-old English Morello cherries in (1) are from a block which was sprayed with bordeaux mixture and casein during the first season, with the results illustrated in (3). Similar two-year-old trees in (2) were from a block which was unsprayed (4) during the first year. Trees in both (1) and (2) were well sprayed with bordeaux mixture and casein during the second year.

more commonly used lime-sulphur for controlling cherry yellow-leaf. However, no critical study of the proper time, method of application or of the relative efficiency of different spray materials had ever been made in Iowa. Poor timing of sprays, haphazard application methods and inefficiency of bordeaux mixture, because of improper preparation of home-made mixtures and use of ineffective commercial mixtures, left much to be desired in the control of the parasite. The possibility of improving bordeaux mixture as it was being used, or of replacing it with some more effective material called for a close study of cherry spraying and dusting.

LIFE HISTORY AND SEASONAL DEVELOPMENT OF THE ORGANISM

There are two stages in the life history of the fungus causing the yellow-leaf disease. As shown in fig. 2, it lives as a parasite on green leaves in the summer and as a saprophyte on dead leaves during the winter. Both modes of life result in spore production, which is the sole means by which the fungus can cause further infection. In order to combat yellow-leaf effectively, the nurseryman must know when these spores will be produced and when conditions are suitable for leaf infection. The chief problem in spraying is to have all susceptible leaf tissue covered with an effective fungicide at the time the spores are disseminated.

Leaves infected late in the summer remain under the trees during the winter. As the soil is warmed in the spring many small round black spots develop ((fig. 2, No. 1) on these leaves. Within each spot (fig. 2, No. 2) are scores of tiny sacs known as asci, each containing eight two-celled spores (fig. 2, No. 3). In 1930 these spores (fig. 2, No. 4) were mature by April 17, and in 1932, by April 29. In the latter year the ascospores were discharged before May 5. Spore discharge usually occurs when about 90 percent of the petals have fallen from fruit-bearing trees and at a time when nursery stock has produced tender foliage which is most subject to attack.

Primary infection of young leaves (fig. 2, No. 5) was observed on May 20, 1929, May 15, 1930, and May 15, 1932. This infection occurred when the shoots of budded trees were from 6 to 12 inches long.

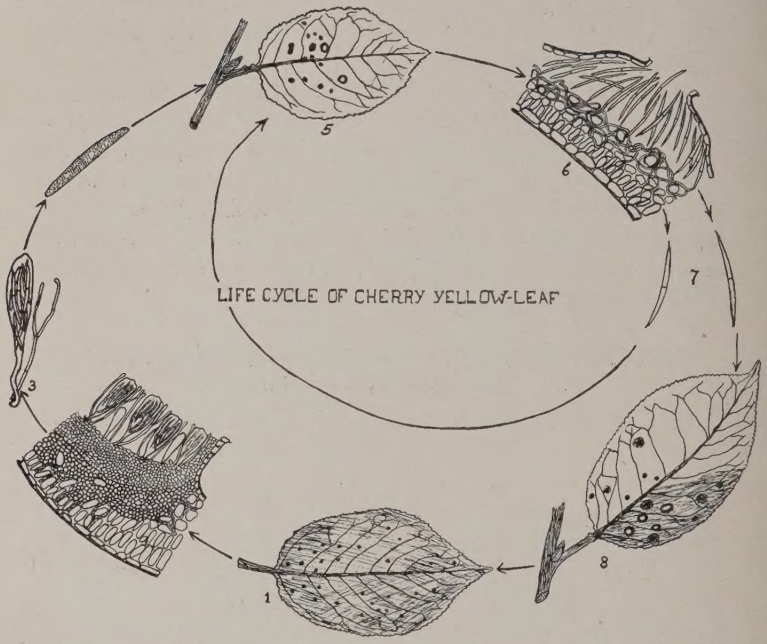

Fig. 2. Stages in the development of the fungus causing cherry yellow-leaf, (1) winter fruiting bodies (apothecia) developing on an old leaf late in April, (2) a cross section through one of these apothecia embedded in the leaf tissue, (3) one of the spore sacs (asci) illustrated in 2 highly magnified, (4) one of the eight ascospores discharged from the ascus after a rain, (5) infection centers produced on a young leaf by ascospores, (6) a cross section through one of the spots in 5 showing leaf tissue below and above covering the fungus masses in the center, (7) spores which are splashed from infected to healthy leaves during rainstorms (several crops of these spores are produced in one summer), (8) late stage of infected leaves (such as shown in 5) in which the leaf is turning yellow and is ready to fall to the ground where the fungus will live through the winter.

The first symptom of infection consists of a tiny, purple-brown fleck in the leaf tissue. This spot enlarges and the tissue in the center dies, leaving a chlorotic ring around the lesion. Blister-like acervuli (fig. 2, No. 6) bearing masses of white summer spores develop on the underside of the leaf, and the infected tissue may drop out later, giving the appearance of a shot hole in the leaf. When many infection centers have developed (fig. 2, No. 8) the leaf becomes yellow and falls. The splashing of water from diseased to healthy leaves during rainstorms is responsible for rapid dissemination of the summer spores or conidia. Mois-

ture is also conducive to spore germination and subsequent penetration and infection of healthy leaf tissue by the fungus. Since several generations of conidia may be produced each season, the new leaves are liable to infection whenever weather conditions are suitable.

The yellow-leaf epidemic of 1929 at Shenandoah, Iowa, was the most severe in the 5-year period, 1929 to 1932. Heavy rains of May 2, 6, 19, 31, June 6, 19, 21, 30, July 6, 13, 14 and 30 of 1929 created ideal conditions for development of the fungus. Severe infection was observed on June 10, especially among unsprayed trees. By July 9, when the seventh spray application was made, the unsprayed trees were practically defoliated, and a difference in the height of sprayed and unsprayed trees was already apparent.

The season of 1930 began normally with heavy showers in April and May, but the amount of rainfall in June was subnormal. Drouth and excessively high temperatures followed July 4. Yellow-leaf disease, which was first observed on May 15, spread slowly during June but infection ceased in July. Spraying was discontinued July 24.

The epidemic in 1931 was mild since the rains were sharp and rarely followed by cloudy, moist weather. Infection was observed first in May, and by June 22 unsprayed trees were severely diseased. Not much defoliation occurred until late in the season, and none of the trees lost all of their leaves.

The season of 1932 was unusual because of the earliness of the period of heaviest infection. Yellow-leaf, observed first on May 15, was spread very rapidly by two heavy rains followed by cloudy weather during the latter part of the month. This infection, promoted by other heavy rains on June 2, 6, 8, 9, 10 and 11, created a severe epidemic on all unsprayed or poorly sprayed trees. By June 15, one-half of the leaves on unsprayed trees had fallen. Further infection was checked by a dry period from June 11 to July 23, and only a moderate epidemic developed late in the season.

MATERIALS AND METHODS USED

Control measure studies recorded here deal mostly with spraying practices and relate especially to application time and effectiveness of certain fungicides.

Control methods for yellow-leaf which were already being used by nurserymen in the Missouri Valley were studied during 1927 and 1928, and small preliminary spraying experiments were undertaken during these two seasons. However, larger experiments, conducted at Shenandoah, Iowa, from 1929 to 1932, inclusive, duplicated most of the earlier work so that it will not be necessary to report these preliminary experiments. The groups of yearling budded cherry trees used for experimental treatments were situated in 3 or 4 adjacent rows which ran the full length of the field. The long strip of land thus occupied was divided into rectangular blocks containing 100 to 200 trees each. Treated and control blocks were alternated; the former containing about twice as many trees as the latter.

Trees in each of the larger blocks were sprayed at regular periods. The liquid sprays were applied with a 3-gallon knapsack sprayer while the dusts were applied with a hand duster. During the 4 years indicated, 30 different fungicidal preparations were used on 67 different blocks of trees.

Height (distance from bud union to the tip of terminal leaf) and caliper (diameter of stem at a point 1 to 2 inches above the bud union) were measured at the close of the first growing season. With the exception of 1929, additional measurements of height were made during midsummer; and, with the exception of 1932, the height and caliper were again measured at the close of the second growing season. During the second season all trees were sprayed alike with bordeaux mixture and casein without regard to former treatment.

Spray materials and dusts used on the 1-year-old stock are listed below. The companies' guaranteed analysis of their respective materials for the years are included. Since the materials in a commercial preparation selling under a trade name are frequently changed, the data presented in the subsequent pages cannot be applied in the future without first ascertaining that the material has the same constitution.

I. COPPER SPRAYS

1. Bordeaux mixture (1929, 1930, 1931, 1932). In 1929 4 pounds of bluestone (copper sulphate) and 4 pounds of rock lime were used in 50 gallons of water. During the remaining years, 6 pounds of *fresh* hydrated lime were substituted for the

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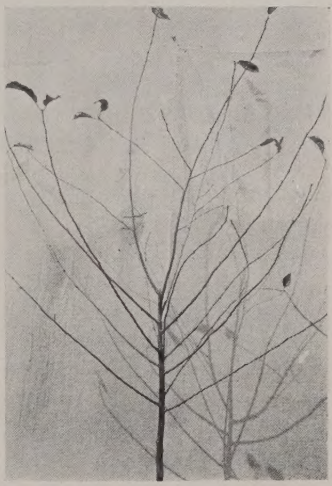

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Fig. 3. Appearance of the foliage on 2-year-old Early Richmond cherries sprayed with different materials. (1) Bordeaux mixture, (2) sulphur dust, (3) sulphur spray, (4) unsprayed.

rock lime. The bluestone was dissolved and diluted to three-fourths of the desired volume, the lime was made into a thin paste and washed through a screen into the bluestone solution. The mixture was made up to volume and thoroughly stirred. Spreaders, when used, were added to this mixture after its preparation.

(2) Bordeaux mixture with casein spreader (1929, 1930, 1931, and 1932).

The commercial preparation Kayso (calcium caseinate containing 80 percent casein and 20 percent calcium hydroxide) was added to bordeaux mixture at the rate of 2 pounds to 100 gallons.

In 1930 and 1931 this mixture was applied at 10-, 20- and 30-day intervals to learn the value of frequency of application. Old infected leaves were piled around the base of the trees in one block in 1931 to test the effect of failure to clean up the old leaves thoroughly in the spring.

(3) Bordeaux mixture with rosin fish oil soap at the rate of 0.5 percent by weight was used in 1930 and 1931.

(4) Bordeaux mixture with oil emulsion at the rate of 1 to 200, by volume, as a spreader, was used in 1930, 1931, 1932. (Central Petroleum oil was used).

(5) Bordeaux mixture and lead arsenate spreader (consisting of 4 percent casein in lead arsenate), 4 pounds to 100 gallons, was used in 1930 and 1931. (Latimer-Goodwin Co.).

(6) Bordeaux mixture and fluxit fixator, 1 pound to 100 gallons, was used in 1930, 1931, 1932. (Colloidal Products Corp.)

(7) Bordeaux mixture, with 4 pounds of zinc sulphate and 1 pound of casein spreader added to each 50 gallons was used in 1930.

(8) "Kelsey spray," consisting of two applications of a mixture of 8 pounds of 200-300 mesh sulphur, 4 pounds of lime and a pound of casein and lime to 50 gallons of water, followed by bordeaux mixture and casein for the remainder of the season, was used in 1931.

(9) Copper fluosilicate, made by the Tennessee Agricultural Experiment Station, was used at the rate of 5 quarts to 50 gallons of water in 1931.

II. ALUMINUM AND ZINC SUBSTITUTES

(10) Aluminum sulphate-lime-casein mix, consisting of 4 pounds of aluminum sulphate and 6 pounds of hydrated lime in 1930 and 6 pounds of aluminum sulphate and 6 pounds of lime

in 1931 was mixed similarly to bordeaux mixture and applied with casein as a spreader.

(11) Zinc sulphate-lime-casein mix, consisting of 4 pounds of zinc sulphate and 6 pounds of hydrated lime in 1930, and of 6 pounds of zinc sulphate and 6 pounds of hydrated lime in 1931 was mixed similarly to bordeaux mixture and applied with casein as a spreader.

III. LIME SULPHUR SPRAY

(12) Lime sulphur. Commercial liquid lime-sulphur (33° Baume) and casein, 1 pound to 50 gallons, was used in all experiments. Lime-sulphur was used at the concentration of 1 gallon in 50 gallons of water in 1929, 1 to 40 in 1930, 1931, 1932, and 1 to 30 in 1930, 1931.

IV. FLOTATION SULPHUR SPRAYS

(These are the by-products of coke-oven gas manufacturing processes.)

(13) Nickel sulphur paste was used in 1929 at the rate of 10 pounds to 100 gallons. This material contained 45 to 48 percent sulphur and 45 to 50 percent water in addition to the insoluble impurities. (Koppers Products Co.)

(14) Ferrox sulphur paste was used in 1929 at the rate of 10 pounds to 100 gallons. This material contained 35 to 48 percent sulphur, 45 to 50 percent water and insoluble impurities. (Koppers Products Co.)

(15) Thylox sulphur paste was used in 1929 at the rate of 10 pounds to 100 gallons. This material contained 45 to 48 percent sulphur, 45 to 50 percent water and insoluble impurities. (Koppers Products Co.)

(16) Flotation sulphur paste was used at the rate of 10 pounds to 100 gallons in 1932. This material contained 45 to 48 percent sulphur and 45 to 50 percent water in addition to impurities. (Koppers Products Co.)

(17) Dry wettable sulphur was used at the rate of 5 pounds to 100 gallons in 1930. This was a wettable sulphur powder analogous to flotation sulphur paste and contained 80 percent sulphur. (Koppers Products Co.)

V. POLYSULPHIDE SULPHUR SPRAY

(18) Soluble sulphur containing 40 percent polysulphide (largely calcium) 18 percent sodium thiosulphate, 3 percent free

sulphur and 39 percent inert matter was applied at the rate of 8 pounds to 100 gallons in 1929. (Niagara Sprayer and Chemical Co.)

VI. COLLOIDAL SULPHUR SPRAY

(19) Colloidal sulphur paste was used at the rate of 6 pounds to 100 gallons in 1932. It contained 70 to 75 percent hydrophyllic colloidal sulphur, 1 to 5 percent non-colloidal sulphur and 20 to 29 percent water containing certain acids (character not specified). (Ansul Chemical Co.)

VII. DRY MIX SULPHUR SPRAY

(20) Dry mix sulphur was used at the rate of 8 pounds to 100 gallons in 1929. It contained 61 percent sulphur. (Niagara Sprayer and Chemical Company.)

VIII. BENTONITE SULPHUR DUST

(21) Kolodust which contained 86.5 percent sulphur and 13.5 percent Kolobase (the company's carrier) and was claimed to be of an irreversible colloidal type was used in 1931 and 1932. (Niagara Sprayer and Chemical Company.)

(22) Kolodust was applied until July 16, then changed to bordeaux mixture with casein spreader for the remainder of the season in 1932.

IX. FLOTATION SULPHUR DUST

(These were the same as the flotation pastes except that they were in powdered form).

(23) Nickel sulphur dust containing 95 to 98 percent sulphur was used in 1929. (Koppers Products Co.)

(24) Ferrox sulphur dust containing 70 to 75 percent sulphur was used in 1929. (Koppers Products Co.)

(25) Thylox sulphur dust containing 95 to 98 percent sulphur was used in 1929, 1930 and 1931. (Koppers Products Co.)

(26) Straight sulphur, a mixture of ferrox and thylox sulphur dust recommended by the company as equivalent to thylox, was used in 1932.

(27) Sulphur blend containing 25 percent flotation sulphur and 75 percent flowers of sulphur was used in 1932. (Koppers Products Co.)

X. DUSTING SULPHUR

(28) 300-mesh sulphur was applied 8 times after 4 applica-

tions of Niagara Sprayer and Chemical Company's 90-10 sulphur dust had been made in 1929.

XI. COPPER DUSTS

(29) Vitidust, containing 12 percent monohydrated copper sulphate, 15.2 percent lead arsenate, and 72.8 percent hydrated lime was used in 1929, 1930, 1931, and 1932. (Niagara Sprayer and Chemical Co.)

(30) D-6 dust containing 20 percent monohydrated copper sulphate and 80 percent hydrated lime was used in 1930 and 1931. (Niagara Sprayer and Chemical Co.)

RESULTS FROM EXPERIMENTAL SPRAYING

1929 EXPERIMENTS

About 2,300 English Morello buds on Mahaleb stocks were divided into 13 spray blocks with intervening checks. Twelve applications of the spray materials listed under fig. 4 were made between May 25 and Aug. 14. The height and caliper of the trees were measured on Sept. 2, 1929. They were measured again on Sept. 1, 1930, after all trees had been sprayed alike with bordeaux mixture and casein during the season of 1930. The height and caliper of trees in each spray block and the unsprayed trees at either end of it (checks) are presented in fig. 4.

1930 EXPERIMENTS

Nine blocks of Early Richmond trees with intervening checks were staked out in April and six additional blocks in the next two rows were staked out without intervening checks in May. The last six blocks were compared to the two unsprayed blocks which were immediately opposite them in the first four rows. The 3,500 trees in these 15 blocks were sprayed eight times between May 15 and July 24 with the materials listed under fig. 5. All blocks except 10 and 11 were sprayed every tenth day. All trees were sprayed alike in 1932 with bordeaux mixture and casein spreader.

1931 EXPERIMENTS

About 4,300 Montmorency trees, budded on Mahaleb stocks, were divided into 19 spray blocks with intervening checks. Ten

applications of fungicides were made between May 15 and Aug. 13 using the various materials listed under fig. 6. All blocks, except 9 and 10, were sprayed every tenth day.

The height of the trees was measured on June 29 while both height and caliper were obtained on Sept. 6, 1931, and Sept. 3, 1932. Percentages of fallen and diseased leaves in seven blocks and their checks were obtained on July 13, 1931, to further test the comparative effectiveness of the treatments. These data are presented in figs. 6 and 8. All trees were sprayed alike in 1932 with bordeaux mixture and casein spreader.

1932 EXPERIMENTS

Two separate blocks of cherries, one containing 2,700 Early

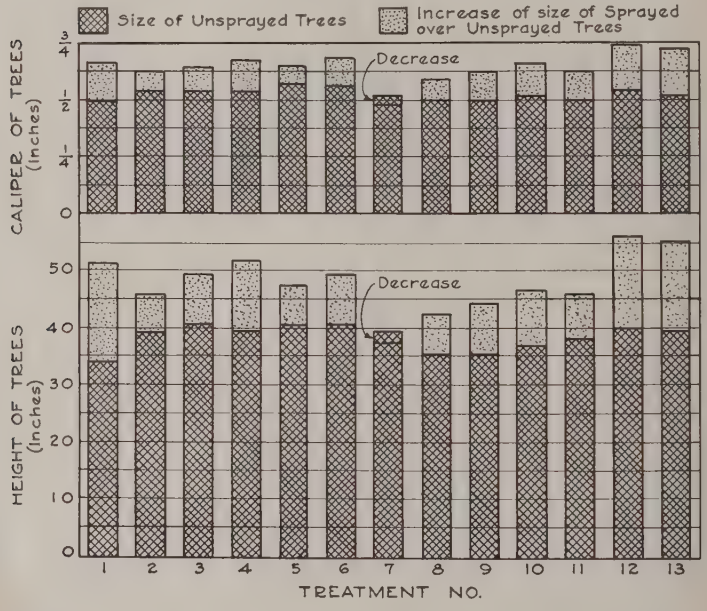

Fig. 4. Height and caliper of unsprayed 2-year-old cherry trees in September, 1930, together with differences between these trees and those sprayed with different materials in 1929. (1) Vitidust, (2) nickel sulphur dust, (3) ferrox sulphur dust, (4) thylox sulphur dust, (5) dusting sulphur, (6) Niagara dry mix, (7) Niagara soluble sulphur, (8) nickel sulphur paste, (9) ferrox sulphur paste, (10) thylox sulphur paste, (11) lime-sulphur 1 to 50, (12) bordeaux mixture and casein, (13) bordeaux mixture without a spreader. The trees were sprayed 12 times with the different materials in 1929, and the checks were not sprayed. In 1930 the trees in both the spray and check blocks were sprayed alike with bordeaux mixture and casein. For discussion see text.

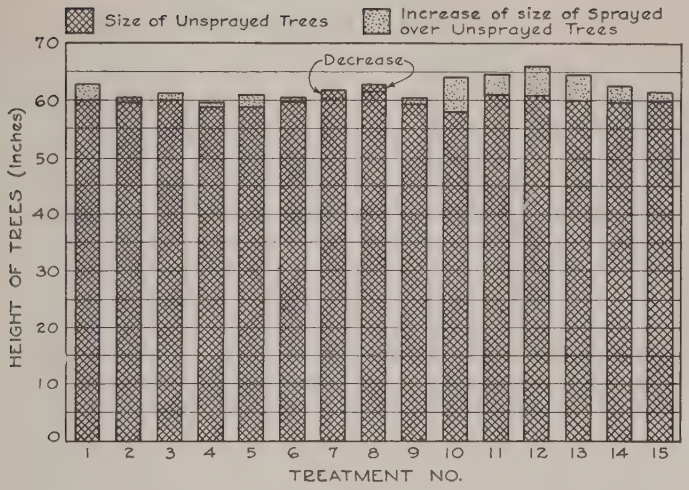

Fig. 5. Height of 2-year-old unsprayed cherry trees September, 1931, together with differences between these trees and those sprayed with different materials in 1930. (1) Bordeaux mixture without a spreader, (2) bordeaux mixture and casein, (3) bordeaux mixture and rosin-fish-oil soap, (4) bordeaux mixture and oil emulsion, (5) bordeaux mixture and lead arsenate spreader, (6) lime-sulphur, 1 to 40, and casein, (7) lime-sulphur, 1 to 30, and casein, (8) Vitidust, (9) thylox sulphur dust, (10) aluminum sulphate-lime-casein mixture, (11) zinc sulphate-lime-casein mixture, (12) bordeaux mixture with zinc sulphate, (13) bordeaux mixture and fluxit fixator, (14) bordeaux mixture and casein once every 30 days, (15) bordeaux mixture and casein once every 20 days. The trees were sprayed eight times in 1930 and all trees (both checks and sprayed ones) were sprayed alike in 1931 with bordeaux mixture and casein. For discussion see text.

Richmond and the other 3,000 Montmorency, were each divided into 13 spray blocks with intervening checks and sprayed nine times between May 17 and Aug. 5. The height of these trees was measured on July 7 and 8 and height and caliper on Aug. 24 and Sept. 5. Since the Early Richmond block was much more uniform only the data from it are presented in fig. 7. The Montmorency block was bordered in part by a planting of mature trees which created unfavorable growing conditions in part of the block. Differences in height and caliper between sprayed and unsprayed trees in this block are presented in table 5.

Leaves on every tenth tree in each treatment were classified according to the degree of infection or defoliation on July 19. These data are presented in fig. 9, with the differences in height between unsprayed and sprayed trees.

NET PROFIT DERIVED FROM SPRAYING CHERRIES

Not only has spraying been found indispensable to the health of nursery stock but it may also be a means of forcing trees into marketable size at the close of the first growing season. The data in table 3, from the 1929 experiments, show that a large proportion of unsprayed trees were killed during the winter and those which survived were of inferior size the second year. Both

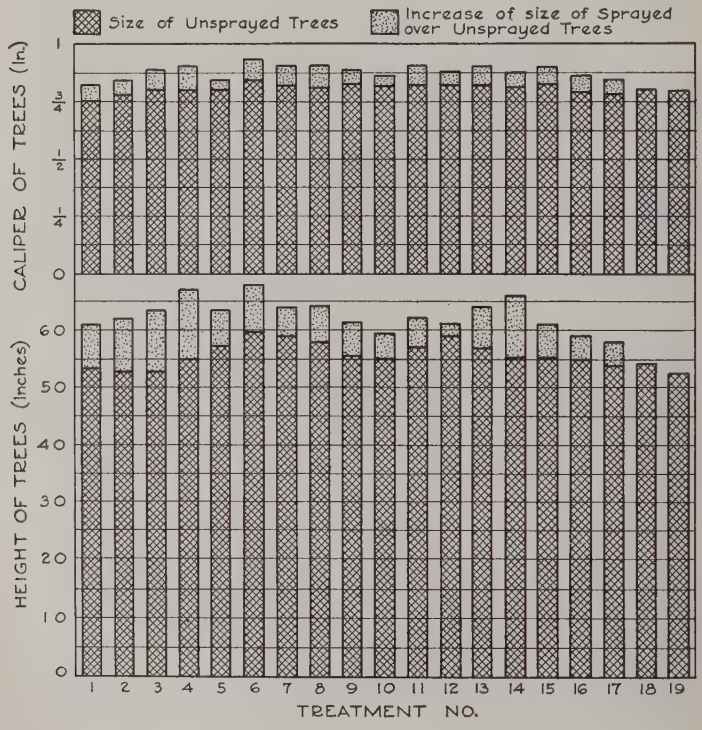

Fig. 6. Height and caliper of 2-year-old unsprayed cherry trees in 1932 with differences between these and trees sprayed with different materials in 1931. (1) Bordeaux mixture without a spreader, (2) bordeaux mixture and lead arsenate spreader, (3) bordeaux mixture and rosin-fish oil soap, (4) bordeaux mixture and fluxit fixator, (5) bordeaux mixture and oil emulsion, (6) bordeaux mixture and casein once every 10 days, with old leaves piled around the base of the trees, (7) bordeaux mixture and casein once every 10 days, (8) calcium mixture, (9) bordeaux mixture and casein once every 20 days, (10) bordeaux mixture and casein once every 30 days, (11) vitidust, (12) D-6 dust, (13) thylox sulphur dust, (14) kolodust, (15) lime-sulphur 1-30 and casein, (16) lime-sulphur 1 to 40 and casein, (17) copper fluosilicate, (18) aluminum sulphate-lime-casein mixture, (19) zinc sulphate-lime-casein mixture. The trees were sprayed 10 times with the respective materials in 1931, and all trees (both checks and sprayed ones) were sprayed alike in 1932 with bordeaux mixture and casein. For discussion see text.

TABLE 1. SPECIFICATIONS AND WHOLESALE PRICES OF DIFFERENT GRADES OF CHERRIES IN 1931 AND 1932.

Grade	Caliper in 1/16"	Height in inches	Branching	Market price	
				1931	1932
11/16	11 to 16	48 and up	branched	$0.20	$0.18
9/16	9 to 11	42 and up	"	.17	.15
7/16	7 to 9	30 and up	"	.14	.12
5/16	5 to 7	24 and up	partly branched	.12	.10
non-salable	less than 5	less than 24	—		—

of these conditions represent direct losses to the nurserymen and become limiting factors in cherry propagation in Iowa.

Since market grades of trees are based upon height and caliper, all differences in growth due to protection of foliage by spraying should increase the value of the trees. The yearling trees in each

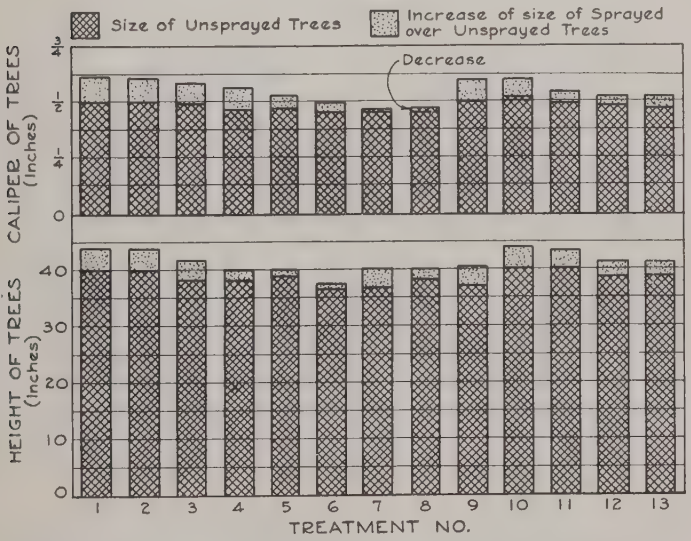

Fig. 7. Height and caliper of unsprayed 1-year-old Early Richmond cherry trees with differences between these and trees sprayed with different materials in 1932. (1) Bordeaux mixture without a spreader, (2) bordeaux mixture and casein, (3) bordeaux mixture and fluxit fixator, (4) bordeaux mixture and oil emulsion, (5) lime-sulphur 1-40 and casein, (6) Ansul's colloidal sulphur, (7) Kopper's flotation paste, (8) Kopper's dry wettable sulphur, (9) kolodust for the first half of the season followed by bordeaux mixture and casein, (10) kolodust, (11) Kopper's straight sulphur dust, (12) Kopper's sulphur blend, (13) vitidust. The trees were sprayed nine times in 1932 and measured in September as 1-year-old stock.

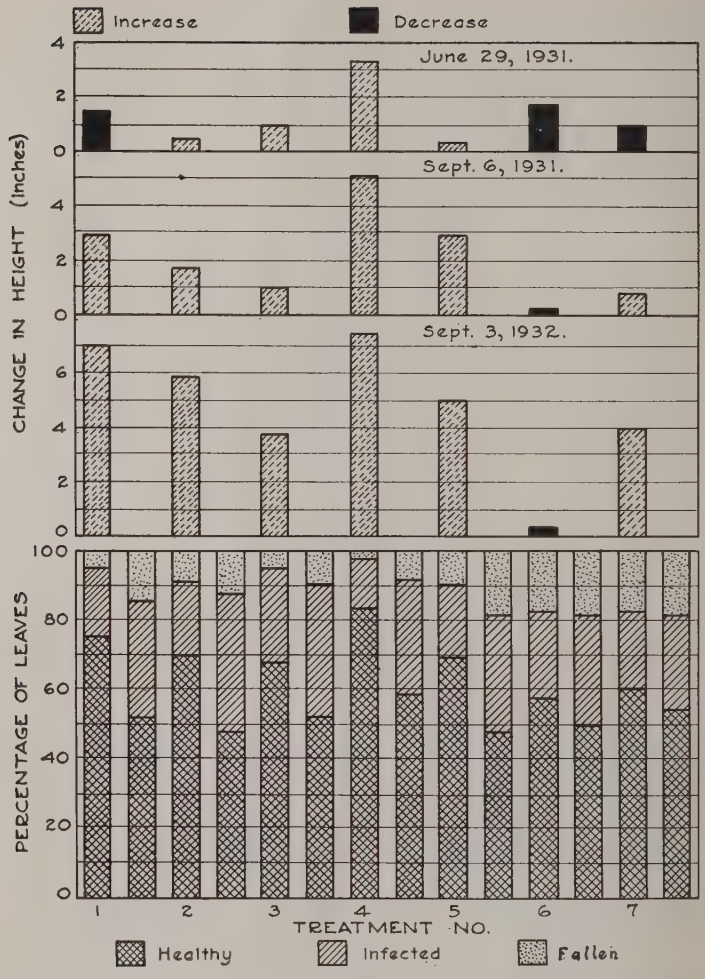

Fig. 8. Percentage of healthy, infected and fallen leaves from Montmorency cherries sprayed with seven materials in 1931 and from their unsprayed checks, with differences in height of sprayed trees and their checks at three dates. (1) Bordeaux mixture without a spreader, (2) bordeaux mixture and casein, (3) lime-sulphur 1 to 30, (4) kolodust, (5) vitidust, (6) aluminum sulphate-lime-casein mixture, (7) copper fluosilicate. The condition of the foliage in the checks for each treatment is indicated in the column to the immediate right of the treatment. The trees were sprayed with these materials throughout their first season (1931) and the leaves were counted on July 13, 1931. All trees (both in the spray block and in the checks) were sprayed alike with bordeaux mixture and casein in 1932. For discussion see text.

block were classified, in 1931 and 1932, into the standard market grades and evaluated at current prices at the close of the season. The market grades and prices are presented in table 1.

All trees in a given treatment were classified according to this scale without reference to root and stem defects which are not related to spraying. The number of trees in a grade was multiplied by the selling price for that grade to give a total value. The total value of all classes was obtained and divided by the

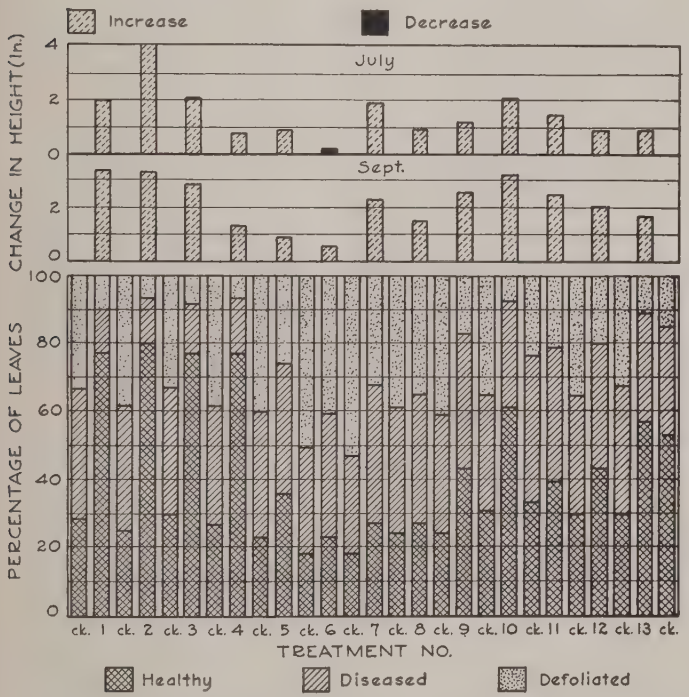

Fig. 9. Percentage of healthy, infected and fallen leaves of Early Richmond cherry trees under different spray treatments in 1932, with the accompanying difference in height between sprayed and unsprayed trees at two different dates. (1) Bordeaux mixture without a spreader, (2) bordeaux mixture and casein, (3) bordeaux mixture and fluxit fixator, (4) bordeaux mixture and oil emulsion, (5) lime-sulphur 1 to 40, and casein, (6) Ansul's colloidal sulphur, (7) Kopper's flotation paste, (8) Kopper's dry-wettable sulphur, (9) kolodust for the first half of the season followed by bordeaux mixture and casein, (10) kolodust, (11) Kopper's straight sulphur dust, (12) Kopper's sulphur blend, (13) vitidust. The graphic sequence is the same as the arrangement of the plots in the field and the unsprayed checks are indicated to either side of their respective treatments. The leaves were counted on July 19, 1932, after the trees had been sprayed seven times with the different materials. For discussion see text.

number of trees in the treatment to give an average value per tree. Data from the 1931 and 1932 experiments are presented graphically in figs. 10 and 11, respectively.

In order to estimate the net profit which might have been expected had these experimental treatments been applied commercially, data on the cost of applying bordeaux mixture with power sprayers were obtained from the two nurseries at Shenandoah, Iowa, where the experiments were conducted. These data are incorporated in table 2.

DISCUSSION OF DATA

THE MOST EFFECTIVE FUNGICIDE

The outstanding fact apparent from the experiments reported in this bulletin is that bordeaux mixture was the most reliable and effective material used. Trees sprayed with it gave a larger increase in growth in comparison to unsprayed trees than did those protected by other fungicides. In normal years, the more effective protection of the leaves against yellow leaf resulted in growth sufficient to obscure the tendency to retard terminal development.

However, there are several other significant general considerations of the relationship between the effectiveness of different fungicides and growth. They will be discussed as (1) the relative effectiveness of sprays and dusts, (2) effectiveness of different spray materials, (3) value of spreaders and stickers, (4) retardation of growth of fungicides, and (5) profits to be derived from spraying.

SPRAYING VERSUS DUSTING

Eight different dusts were used on 20 blocks of trees and 19 different spray materials on 47 blocks. Not one of the dust treatments induced a greater increase in growth over its checks than did the best spray treatment for the same year. Thylox and vitidust in 1929, and kolodust in 1931 and 1932, however, gave almost as large increase in growth as the better sprays. The two former dusts were much less effective in promoting growth than bordeaux mixture in 1929 (table 3), but by the end of the second season (fig. 4) trees dusted with them showed about the same gain in height. However, further tests in 1931 (fig. 6) failed to confirm this finding since dusted trees were largely

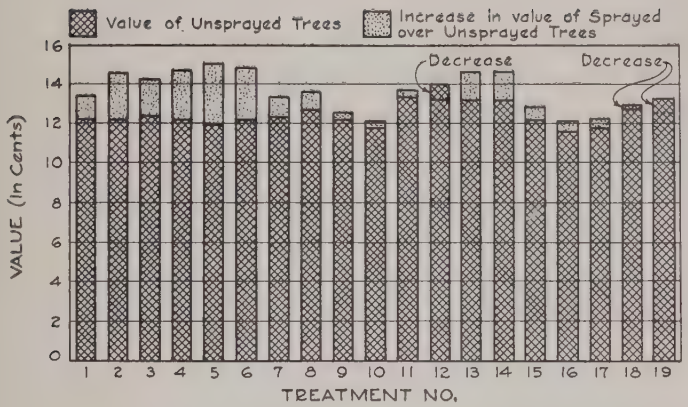

Fig. 10. Average market price of unsprayed 1-year-old Montmorency cherry trees with differences in value of trees sprayed 10 times with different materials in 1931. (1) Bordeaux mixture without a spreader, (2) bordeaux mixture and lead arsenate spreader, (3) bordeaux mixture and rosin-fish-oil soap, (4) bordeaux mixture and fluxit fixator, (5) bordeaux mixture and oil emulsion, (6) bordeaux mixture and casein with old leaves heaped around the base of the trees, (7) bordeaux mixture and casein once every 10 days, (8) Kelsey mixture, (9) bordeaux mixture and casein once every 20 days (10) bordeaux mixture and casein once every 30 days, (11) vitidust, (12) D-6 dust, (13) thylox sulphur dust, (14) kolodust, (15) lime-sulphur, 1 to 30, and casein, (16) lime-sulphur, 1 to 40, and casein, (17) copper fluosilicate, (18) aluminum sulphate-lime-casein mixture, (19) zinc sulphate-lime-casein mixture. The trees were measured in September and classified into the standard market grades strictly according to size. Root and stem defects were ignored since they are not influenced by spraying. The trees were evaluated at wholesale prices (Table 1) then being quoted for the various grades.

defoliated and showed only a moderate gain in size over their checks.

Kolodust appeared to be as effective as bordeaux mixture in 1931. Trees dusted with it showed less infection by midsummer (fig. 8) and practically the same increase in height over their checks as those sprayed with bordeaux mixture. In a season of heavy infection, such as early summer of 1932, trees dusted with kolodust were rather heavily infected (fig. 9). The latter part of the season was dry and kolodust very effectively checked the disease, so the trees showed considerable increase in size. However, kolodust had been found to be ineffective during prolonged rainy periods. The sulphur dusts in general, were more effective than the copper dusts. Kolodust was the outstanding sulphur dust during the two years it was used, but it was found ineffective during the heavy early season epidemic of 1932. Its use, therefore, must be confined to seasons of moderate rainfall when it may be substituted very effectively for sprays.

TABLE 2. COST OF SPRAYING CHERRIES IN TWO COMMERCIAL NURSERIES AT SHENANDOAH, IOWA IN 1932.

Items of expense	Nursery A				Nursery B			
	One-year-old trees		Two-year-old trees		One-year-old trees		Two-year-old trees	
	Cost	Amount used	Cost	Amount used	Cost	Amount used	Cost	Amount used
Upkeep and depreciation on sprayer*	$ 26.64	50% of total time**	$ 14.80	27.7% of total time**	$ 7.08	20% of total time***	$ 1.79	5% of total time***
Cost of spray materials:								
Bluestone at 5.8c per lb.	104.40	1800 lb.	58.00	1000 lb.	90.94	1568 lb.	18.56	320 lb.
Hydrated lime at 1.0c per lb.	27.00	2700 lb.	15.00	1500 lb.	23.52	2352 lb.	4.80	480 lb.
Labor and teams used in applying	144.00	18 days at 8.00	80.00	10 days at 8.00	167.20	22 days at 7.60	34.20	4.5 days at 7.60
Cost of hauling materials to field	27.00	36 hrs. at .75c	15.00	20 hrs. at .75c	55.48	7.3 days at 7.60	11.40	1.5 days at 7.60
Total cost	329.04		182.80		344.22		70.75	
Number of trees		140,000		90,000		104,000		65,000
Cost per tree	0.00235		0.00203		0.00331		0.00109	

*Both nurseries used Bean Power Sprayers and expected 15 years service from them.
**Annual cost of depreciation and upkeep, $53.28.
***Annual cost of depreciation and upkeep, $35.40.

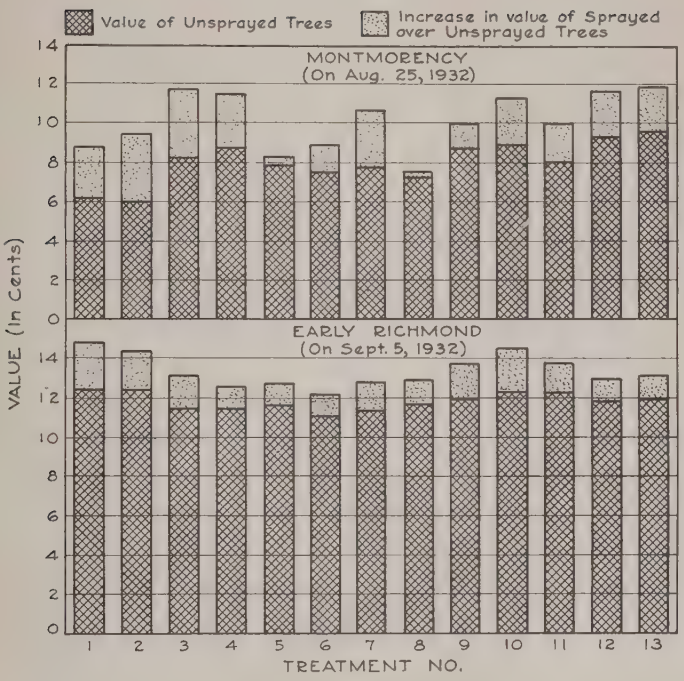

Fig. 11. Average market price of unsprayed 1-year-old trees in 1932 of two varieties of cherries with differences in value of trees sprayed with 13 different fungicides. (1) Bordeaux mixture without a spreader, (2) bordeaux mixture and casein, (3) bordeaux mixture and fluxit fixator, (4) bordeaux mixture and oil emulsion, (5) lime-sulphur, 1 to 40, and casein, (6) Ansul's colloidal sulphur, (7) Kopper's flotation paste, (8) Kopper's dry-wettable sulphur, (9) kolodust for the first half of the season followed by bordeaux mixture and casein, (10) kolodust, (11) Kopper's straight sulphur dust, (12) Kopper's sulphur blend, (13) vitidust. The trees were sprayed nine times in 1932 and measured in September and classified into market grades strictly according to size. The various classes were evaluated at current wholesale market prices (Table 1).

These findings concerning dusting have been confirmed by Young (13) and others, but Stewart (10) in 1917 found that nursery stock dusted with a sulphur-lead arsenate (90 to 10 parts) mixture suffered less infection than that sprayed with lime-sulphur. Stewart did not use bordeaux mixture, but two years previously (11) reported that bordeaux and lime-sulphur were about equally efficient.

RELATIVE EFFECTIVENESS OF DIFFERENT SPRAY MATERIALS

Although lime-sulphur is generally recommended, nurserymen

TABLE 3. HEIGHT AND CALIPER OF ENGLISH MORELLO CHERRIES SPRAYED WITH 13 DIFFERENT FUNGICIDES IN 1929 AND UNSPRAYED TREES ADJACENT TO THEM.

Spray treatment	Measurements on Sept. 2, 1929					Measurements on Sept. 1, 1930					Percentage of trees surviving winter
	No. of trees	Average tree		Average increase		No. of trees	Average tree		Average increase		
		Height*	Caliper**	Height	Caliper		Height	Caliper	Height	Caliper	
Vitidust	82	30.38	6.38**	7.70	2.00	81	51.55	10.58	18.63	3.02	98.7
Checks	69	22.68	4.38			36	32.92	7.56			52.2
Nickel dust	79	25.33	5.65	1.08	1.14	80	46.38	9.72	6.87	1.39	100.0
Checks	79	24.25	4.51			45	39.51	8.33			47.0
Ferrox dust	77	28.81	5.86	4.81	1.40	80	49.12	10.06	9.45	1.88	100.0
Checks	81	24.00	4.46			45	39.67	8.18			55.6
Thylox dust	91	29.51	6.56	6.86	2.29	92	52.50	10.89	13.04	2.44	100.0
Checks	89	22.65	4.27			56	39.46	8.45			62.9
Dusting sulphur	76	26.87	5.67	4.01	1.21	76	47.68	10.17	6.77	1.17	100.0
Checks	80	22.86	4.46			55	40.91	9.00			68.8
Dry mix	69	26.46	6.20	5.63	1.89	68	49.28	10.91	8.32	2.06	98.6
Checks	72	20.83	4.31			46	40.96	8.85			63.9
N. Sol. sulphur	63	11.44	3.47	−8.69	−0.51	5	37.60	7.20	−0.86	−0.90	7.9
Checks	87	20.13	3.98			41	38.46	8.10			47.1
Nickel paste	87	22.40	5.05	2.07	0.87	76	41.68	9.27	6.76	1.77	87.3
Checks	76	20.33	4.18			26	34.92	7.50			34.2
Ferrox paste	70	24.30	5.37	1.55	0.76	67	43.50	9.95	8.89	2.17	85.7
Checks	56	22.75	4.61			23	34.61	7.78			41.1
Thylox paste	93	25.15	5.60	3.20	1.33	87	46.11	10.47	9.82	2.73	93.5
Checks	77	21.95	4.27			35	36.29	7.74			45.5
Lime-sulphur, 1–50	145	25.35	5.46	3.96	1.36	124	45.65	9.87	8.02	2.07	85.5
Checks	96	21.39	4.10			53	37.63	7.80			55.2
Bord. +Casein	121	34.10	7.43	11.77	3.13	124	55.33	11.37	16.33	3.02	100.0
Checks	105	22.33	4.31			67	39.00	8.07			63.8
Bord. (alone)***	219	29.03	6.58	6.13	2.16	209	55.14	11.25	16.66	3.43	95.4
Checks	123	22.90	4.42			50	38.48	7.82			40.7

*Height expressed in inches.
**Caliper expressed in 1/16 of an inch. For instance 6.38 is a tree slightly over 6/16 of an inch in caliper.
***No spreader added.

TABLE 4. INCREASE IN SIZE OF EARLY RICHMOND CHERRIES SPRAYED WITH DIFFERENT MATERIALS OVER UNSPRAYED STOCK.

Treatment	Increase in size of trees sprayed in 1930					Increase in size of trees sprayed in 1932		
	June 20, 1930	Sept. 6, 1930		Sept. 7, 1931		July 7, 1932	Sept. 5, 1932	
	Height*	Height	Caliper**	Height	Caliper	Height	Height	Caliper
Bord. (alone)	−1.09	+1.90	+0.83	+2.82	+0.82	1.98	3.76	1.66
Bord. +casein 1–10 days	−0.69	−0.87	−0.07	+0.39	+0.24	4.08	3.56	1.65
Bord. +casein 1–20 days	−1.38	−0.85	−0.20	+1.88	+0.05			
Bord. +casein 1–30 days	−1.25	+1.37	−0.03	+2.12	−0.34			
Bord. +rosin fish oil	−1.25	−0.06	−0.33	+0.55	−0.27			
Bord. +oil	−1.47	−0.65	−0.06	+0.16	+0.04	0.59	1.34	1.56
Bord. +lead arsenate spreader	−1.00	+1.14	+0.10	+2.47	+0.53			
Bord. +fluxit	−1.38	+0.11	−0.13	+4.79	−0.53	2.16	2.86	1.49
Bord. +zinc sulphate	+0.89	+2.78	+0.18	+5.23	−0.49			
Zinc sulphate mix	+0.19	+1.74	+0.08	+2.09	−0.97			
Aluminum sulphate mix	−0.25	+1.71	+0.21	+3.91	+0.07			
Lime-sulphur, 1–40	−1.13	+1.40	+0.55	+0.53	+0.13	0.81	0.95	0.99
Lime-sulphur, 1–30	−0.24	+0.33	+0.42	−1.77	−0.69			
Vitidust	−0.67	−0.28	−0.12	−0.72	−0.11	0.40	1.87	0.87
Thylox dust	−0.15	+1.47	+0.31	+0.62	+0.05			
Colloidal Sulphur						−0.29	0.48	0.62
Flotation Sulphur						1.92	2.31	0.05
Dry wettable Sulphur						0.93	1.63	−0.29
Kolodust, Bord.						1.04	2.60	1.25
Kolodust						2.06	3.41	1.02
Straight Sulphur						1.46	2.52	0.81
Sulphur blend						0.96	2.14	0.86

*Height expressed in inches.

**Caliper expressed in 1/16 inch.

in the Missouri Valley found it ineffective and resorted to bordeaux mixture. This practice is justified by all the data obtained on lime-sulphur used at the concentration of 1 gallon (33° Baume) in 30, 40 or 50 gallons of water. Lime-sulphur was observed to be effective at mid-season in 1929, but trees sprayed with it were almost defoliated by the end of the season. In all other years trees sprayed with this material suffered heavy defoliation and showed a smaller difference in size when compared to unsprayed trees than those sprayed with bordeaux mixture.

Trees sprayed with bordeaux mixture showed the largest increase in size over their checks of any sprayed group for a given year. Bordeaux mixture was most effective when used with a spreader in 1929 and 1931 and on Montmorency cherries in 1932. The Early Richmond block in 1932 showed practically the same gain (fig. 7) when bordeaux mixture was used without a spreader or with casein and fluxit.

None of the "colloidal," "wettable," and "paste" sulphur sprays were sufficiently effective to warrant recommendation.

Their failure seemed to be due to their inability to spread and adhere to the leaves in a uniform film. These data are in conflict with those of Smith (9) who found flotation sulphur nearly as effective in nursery plantings as bordeaux and of Gloyer (6) who suggests wettable sulphur for the last spray on orchard trees. The only exception in these experiments was in the case of Montmorency stock sprayed with flotation paste in 1932. Although the trees showed gains in height over their checks, equivalent to those sprayed with bordeaux mixture, they were practically defoliated by Aug. 15, while those sprayed with bordeaux mixture retained more than 90 percent of their foliage.

USE OF SPREADERS AND STICKERS

At the end of the 1929 season (table 3) bordeaux mixture proved to be superior as indicated in a preliminary report by Bliss (2). Trees sprayed with bordeaux mixture without a spreader, however, showed a net increase in height of 6 inches over their checks as one-year-old stock, while those sprayed with bordeaux mixture and casein showed a gain of 11 inches in height. The same relation was observed in the 1931 experiments and the Montmorency block in 1932. Fluxit fixator and oil emulsion served a similar capacity in 1931 (table 5).

Measurements made at the close of the second season after spraying all trees uniformly, however, show that these differences were not so pronounced as at the close of the first season. The trees sprayed with different materials in 1929 showed gains in September, 1930, of 16.3 inches where a spreader was used and 16.7 inches where bordeaux was used without a spreader. It is well to point out that the severe winterkilling in the checks during the winter of 1929 really changed the character of these blocks leaving only the more hardy checks for comparison in 1930. Similarly in 1931, the differences between trees sprayed with bordeaux and a spreader and bordeaux without a spreader were less pronounced (table 5) by the time the trees were ready to be harvested. This would indicate that spreader is very desirable on trees to be marketed as 1-year-olds, but trees which are to be left in the row for 2 years are nearly as large when sprayed with bordeaux mixture without a spreader as with it the first season.

Trees sprayed with bordeaux mixture without a spreader are as well protected as those sprayed with bordeaux and a spreader.

TABLE 5. INCREASE IN SIZE OF MONTMORENCY CHERRIES SPRAYED WITH DIFFERENT MATERIALS OVER UNSPRAYED STOCK. HEIGHT EXPRESSED IN INCHES AND CALIPER IN ONE-SIXTEENTH OF AN INCH.

Treatments	Increase in size of trees sprayed in 1931					Increase in size of trees sprayed in 1932		
	June 19, 1931	Sept. 6, 1931		Sept. 3, 1932		July 8, 1932	August 24, 1932	
	Height	Height	Caliper*	Height	Caliper*	Height	Height	Caliper*
Bord. (alone)	−1.56	2.43	1.27	7.04	1.01	2.62	4.17	0.77
Bord. +lead arsenate spreader	0.41	4.44	1.52	7.62	0.63			
Bord. +rosin fish oil	0.26	3.43	1.37	8.62	1.06			
Bord. +fluxit	0.79	5.88	1.58	10.24	1.62	1.58	4.19	1.73
Bord. +oil	1.89	5.38	1.60	4.98	0.43	3.30	2.09	1.41
Old leaves, Bord.	−0.77	2.89	1.41	7.86	1.77			
Lime-sulphur, 1–30	0.95	0.58	0.82	4.20	1.40			
Lime-sulphur, 1–40	−0.34	−0.11	0.47	3.16	1.10	0.21	−0.65	0.78
Kolodust	2.90	4.59	0.82	7.53	1.19			
Bord. +casein, 1–10 days	0.18	1.47	1.07	5.29	1.09	2.43	6.93	1.35
Kelsey mix	−0.54	1.46	1.07	6.26	1.22			
Bord. +casein, 1–20 days	0.15	3.11	0.80	4.89	0.83			
Bord. +casein, 1–30 days	0.07	0.31	0.82	2.90	0.46			
Vitidust	0.01	1.86	1.10	5.00	1.18	0.87	3.76	1.06
D-6 dust	0.57	−0.09	0.36	1.25	0.51			
Thylox	1.83	3.45	1.02	6.54	1.19			
Aluminum sulphate mix	−1.90	−0.05	0.02	−0.64	−0.09			
Zinc sulphate mix	−0.99	−1.34	0.02	−1.50	0.25			
Copper fluosilicate	−1.20	0.54	0.28	4.61	0.80			
Colloidal Sulphur						1.22	3.02	1.08
Flotation Sulphur						2.13	4.58	1.69
Dry wettable Sulphur						0.18	−1.31	−0.36
Kolodust, Bord.						0.37	0.43	0.71
Straight Sulphur						0.72	1.77	0.73
Kolodust						2.58	3.66	1.32
Sulphur blend						1.22	3.20	1.65

*Caliper expressed in 1/16 inch.

By midseason (figs. 8 and 9) the trees had about the same percentage of healthy and infected leaves in the two treatments. Then why should the trees consistently show less gain at the end of the first season when the spreader has been omitted? The answer might lie in the difference in early season retardation of growth.

RETARDATION OF GROWTH BY SPRAY MATERIALS

In 1929, the benefits derived from spraying were so pronounced and were realized so early in the season that the retardation of growth from spraying was not realized. However in 1930 when the unsprayed blocks were free of infection and suffered no defoliation, 13 of the 15 spray blocks (fig. 12) showed varying de-

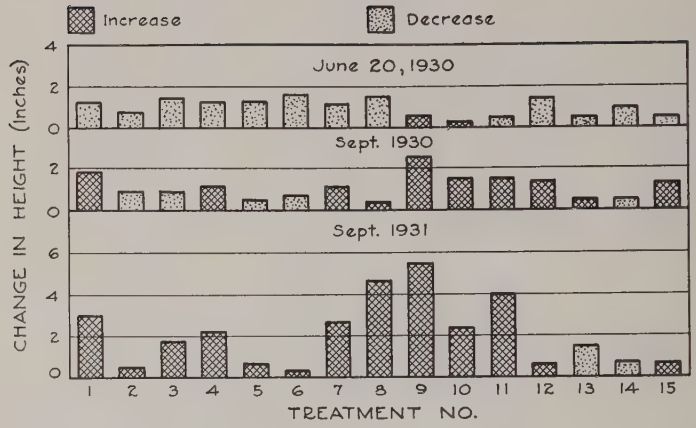

Fig. 12. Differences in height between Early Richmond cherries sprayed with 15 different materials during a season of light infection (1930) and their respective checks at three different dates. (1) Bordeaux mixture without a spreader, (2) bordeaux mixture and casein once every 10 days, (3) bordeaux mixture and casein once every 20 days, (4) bordeaux mixture and casein once every 30 days, (5) bordeaux mixture and rosin-fish oil soap, (6) bordeaux mixture and oil emulsion, (7) bordeaux mixture and Latimer-Goodwin lead arsenate, (8) bordeaux mixture and fluxit fixator, (9) bordeaux mixture and zinc sulphate, (10) zinc sulphate-lime-water mixture, (11) aluminum sulphate-lime-water mixture, (12) lime-sulphur, 1 to 40, and casein, (13) lime-sulphur, 1 to 30, and casein, (14) vitidust, (15) thylox sulphur dust. The trees were sprayed eight times in 1930 with the various materials and all trees (both in the spray block and the checks) were sprayed alike in 1931 with bordeaux mixture and casein. For discussion see text.

grees of retardation in height by June 20. Such a common occurrence was very suggestive. Later studies on these trees showed that those which were not retarded (as in treatment 9) maintained the largest gains up to the time that the trees were harvested.

The same retardation was observed in seven of the 19 treatments in 1931 (fig. 13) by June 29, even though there was a mild epidemic which partially defoliated the unsprayed blocks. However, by September yellow-leaf had injured the checks so that only four blocks of sprayed trees showed a negative height relationship and by September, 1932, all but two were taller than their checks. In other words, the spray materials protected the plants from the pathogene sufficiently to compensate for the injurious effects of the spray material.

This apparent retardation of growth seems to be common to the use of bordeaux mixture, especially when used without a spreader. In 1930 no difference was observed in the relative retardation by bordeaux where a spreader was used and where it

was not, but in 1931 the difference was pronounced. On the Early Richmond block in 1932 the trees sprayed with bordeaux mixture and casein showed a much larger early season growth as compared to its checks than did those sprayed with bordeaux mixture alone. Kolodust and thylox dust did not cause a retardation of growth; so in seasons of light infection when these chemicals could control the disease, trees dusted with them would have a growth advantage.

FREQUENCY OF SPRAYING

An attempt was made to formulate a guide for frequency of spraying, although any spray schedule must be adjusted to different conditions. In 1929, for example the severe epidemic

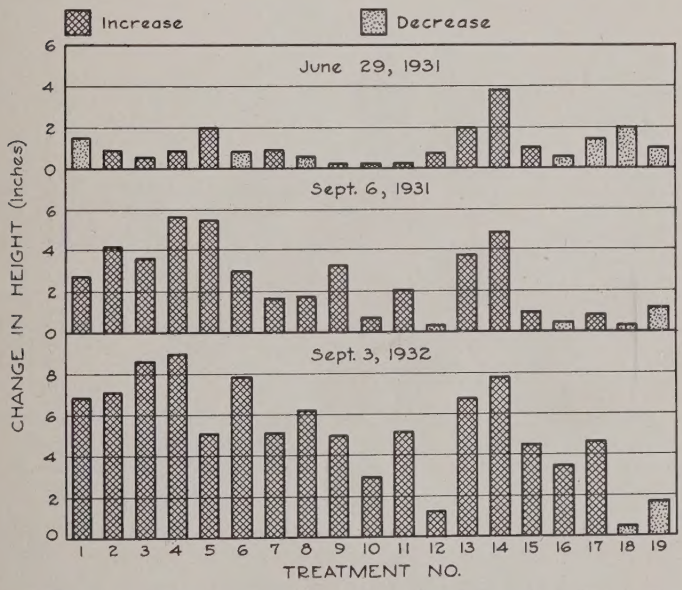

Fig. 13. Differences in height between Montmorency cherries sprayed with 19 different materials in 1931 and their respective checks on three different dates. (1) Bordeaux mixture without a spreader, (2) bordeaux mixture and Latimer-Goodwin lead arsenate spreader, (3) bordeaux mixture and rosin-fish oil soap, (4) bordeaux mixture and fluxit fixator, (5) bordeaux mixture and oil emulsion, (6) bordeaux mixture and casein with old leaves around the trees, (7) bordeaux mixture and casein once every 10 days, (8) Kelsey mixture, (9) bordeaux mixture and casein once every 30 days, (11) vitidust, (12) D-6 dust, (13) thylox sulphur dust, (14) kolodust, (15) lime-sulphur, 1 to 30, and casein, (16) lime-sulphur, 1 to 40, and casein, (17) copper fluosilicate, (18) aluminum sulphate-lime-casein mixture, (19) zinc sulphate-lime-casein mixture. The trees were sprayed 10 times with the different materials in 1931, and all trees (both checks and sprayed ones) were sprayed alike with bordeaux mixture and casein in 1932. For discussion see text.

TABLE 6. PERCENTAGE OF CHERRY LEAVES FALLEN, INFECTED AND HEALTHY UNDER DIFFERENT SPRAY TREATMENTS IN 1931 AND 1932.

Treatments	Percentage of leaves on Early Richmond in 1932			Percentage of leaves on Montmorency in 1931		
	Fallen	Infected	Healthy	Fallen	Infected	Healthy
Bord. (alone)	6.4	17.3	76.3	4.94	21.42	73.63
Check	36.3	37.4	26.3	10.42	35.90	53.67
Bord. +casein	5.5	14.3	80.1	8.17	22.78	69.04
Check	36.5	36.0	27.5	13.34	39.43	47.22
Bord. +Fluxit	8.2	14.8	77.0			
Check	36.4	35.0	38.6			
Bord. +oil	6.8	17.0	76.1			
Check	39.8	35.4	24.8			
Lime-sulphur, 1–40	25.7	39.3	35.0			
Check	45.5	34.4	20.1			
Colloidal sulphur	41.3	35.3	23.4			
Check	51.4	31.0	17.6			
Flotation sulphur	31.6	41.0	27.3			
Check	45.5	32.8	21.7			
Dry wettable sulphur	35.9	36.5	27.5			
Check	40.1	34.1	25.8			
Kolodust-Bord.	16.2	40.4	43.4			
Check	38.6	32.9	28.5			
Kolodust	8.0	31.4	60.0	1.28	14.81	83.91
Check	29.9	37.3	32.7	6.70	33.89	59.40
Straight sulphur	22.7	39.1	38.2			
Check	29.3	39.0	31.7			
Sulphur blend	19.4	34.8	45.8			
Check	33.7	37.0	29.3			
Vitidust	11.7	30.8	57.4		21.30	69.57
Check	26.1	34.9	39.0	18.61	34.25	47.14
Lime-sulphur, 1–30				4.95	27.97	67.08
Check				9.55	38.90	51.55
Aluminum sulphate				16.63	26.46	56.91
Check				18.80	32.28	48.92
Copper fluosilicate				15.57	24.66	59.77
Check				16.59	30.28	53.13

justified frequent application. In 1930 additional sprays after the first two or three were not needed. The first spray must be applied when the stock is 6 to 12 inches tall.

Although the interval between applications will vary with weather conditions, it will not exceed 10 or 15 days. In 1931 the different blocks which were sprayed once every 10, 20, and 30 days with bordeaux mixture and casein showed an average increase in height over their respective checks, of 5.29, 4.89, and 2.90 inches, respectively. If all 19 treatments applied in 1931 were divided into three classes based upon the increase in height over the respective checks, bordeaux and casein applied once every 10 days would fall in the first class, once every 20 days in the second, and once in 30 days in the third and poorest class.

PROFITS FROM SPRAYING

As shown in figs. 10 and 11, the increase in value of yearling stock amounts to 1.00 to 3.03 cents per tree in the better treatments. The actual cost of applying bordeaux mixture under nur-

sery conditions ranged from 0.2 to 0.3 of a cent per tree for the first year. If 30 percent of the trees were graded out, dut to root and stem defects, the cost per marketable tree would be only 0.3 to 043 of a cent per tree. The returns would, therefore, be from 2 to 9 times the cost of spraying, depending upon differences in cost of spraying and relative increase in growth.

A poor spray or a good spray poorly applied gives low returns. The returns on such ineffective treatments as lime-sulphur, vitidust, or copper fluosilicate (1931) were equal to or less than the cost of spraying. Bordeaux mixture applied once every 10 days showed a good profit, but when applied once in 20 or 30 days, the gain in market value just about equalled the cost of spraying.

SUMMARY

Sprayed trees grow more than unsprayed ones because the fungicide prevents defoliation by the fungus *Coccomyces hiemalis*. Trees sprayed with some of the better fungicides such as bordeaux mixture grew more than unsprayed trees even though the fungicide retarded growth.

All of the fungicides used, which were not seriously injurious to the young tree, showed some benefit. Only homemade bordeaux mixture 4-6-50 showed profitable and consistent gains. Although kolodust was satisfactory during one season and did not appear to retard growth as did bordeaux mixture, it failed when substituted for bordeaux during a period of heavy rainfall.

The effectiveness of bordeaux mixture was improved by the addition of a spreader such as casein, fluxit fixator, rosin-fish oil soap or oil emulsion. Although trees sprayed with the fungicide and a spreader showed more increase in height at the end of the first growing season than those sprayed with the fungicide alone, the differences were less pronounced by the end of the following season.

Trees ordinarily should be sprayed about once every 10 days depending upon weather conditions, from the time the plants are 6 to 12 inches high (about May 15) until the growing season is about over (Aug. 15 to 30). In 1930 spraying was discontinued in July, but in all other years it was necessary to continue until the middle of August or later.

Sprays appear, in general, to be more desirable than dusts because they are less easily removed by rain. Dusts are more easily

applied, but their practical use seems to be confined to seasons of light infection.

Kolodust, a sulphur dust, was the most desirable dust used in these trials. It was as effective as bordeaux in 1931 when the rainfall was light.

Spore dispersal from old leaves under the trees in early spring and from infected leaves on the trees during the summer occurs during rainstorms. The purpose of spraying should be to cover the entire leaf area with an effective fungicide before spore dispersals occur.

Since the fungicide sold under any trade name may be varied by the manufacturer, the data presented in this bulletin cannot be applied to the commercial mixtures beyond the years in which they were used. The grower should check the analysis of any of the materials offered to him under the trade names reported in this bulletin and compare it with that given on pages 160-165.

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